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Field Test Data for Detecting Vibrations of a Building Using High-Speed Video Cameras

by Caitlin P Conn and Geoffrey H Goldman

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Sensors and Electron Devices Directorate, ARL

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14. ABSTRACT

The Acoustics Branch at the US Army Research Laboratory (ARL) collaborated with Booz Allen Hamilton, a government consulting firm, to conduct a field test that was designed to assess how high-speed video cameras can be used to detect sound. The team set up a low-frequency ServoDrive speaker inside of ARL's Building 108 facility. In this experiment, the speaker generated tones at 19, 28, and 37 Hz. A RED Scarlet Dragon Camera, Casio Camera, and Point Grey Camera were used to measure video of a vibrating door and window located on the building. In addition, a Polytech laser Doppler vibrometer, 3-axis Geophone, and 2 B&K microphones were stationed close to the building to collect ground-truth data. The field test and the data collected are documented in this report. The team developed image processing algorithms to analyze the results and successfully verified that the cameras and other devices correctly estimated the frequency of the tone generated at each trial.

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1. Introduction

The US Army Research Laboratory's (ARL) Acoustic and Electromagnetic Sensing Branch is developing sensing technologies that use acoustic and seismic methods to detect sound and vibrations on and off the battlefield. Many of these methods use traditional sensors such as microphones, lasers, geophones, and accelerometers. Each of the sensors have their own limitations and advantages as they perform differently in terms of range, accuracy, speed, concealment, and so on. ARL is currently investigating using video cameras to measure vibrations of objects. ARL and Booz Allen Hamilton (BAH) collaborated on a field test in June 2016 to evaluate the feasibility of using video cameras to detect vibrations excited by low-frequency soundwaves. Although video cameras will not be as sensitive as other traditional sensors, cameras are ubiquitous in society and can potentially be used to provide additional information to the Soldier.

2. Motivation and Vision for Military Applications

Video cameras have several advantages over other sound detection devices. These devices tend to be inexpensive compared to other technology, such as laser sensors and radar detection systems. A recent study, led by a collaboration between scientists and researchers of the Massachusetts Institute of Technology, Microsoft, and Adobe, utilized high-speed video cameras that sampled between 2 to 20 kHz to monitor human conversation.[1]

The goal of this experiment was to reconstruct human speech by extracting audio from video data. Video cameras recorded the vibrational behavior of a variety of objects as they were excited, each with different material characteristics. A potted plant, bag of chips, box of tissues, and a glass of water were the objects of concentration in this experiment. Conducting separate tests, each object was placed at a distance ranging approximately 0.5 to 2 m away from the source. During each test run, live-speech conversation was amplified, which excited the specific object of interest. The vibrations of the objects were recorded using the high-speed cameras. Image processing algorithms and acoustic techniques were used to play back the original sound source. This research demonstrated that video cameras can be used for more than just capturing visual images for the Army. In summary, video cameras have the capability to enhance surveillance mechanisms and provide a means for detecting sound.

3. Methods, Assumptions, and Procedures

3.1 Location

In June 2016, ARL conducted a field test with BAH at ARL Building 108 to test the feasibility of using video cameras to detect low-frequency tones within a building. Building 108 is a single-story building that contains a large room. It is a wood-framed building, covered with a vinyl exterior. Within the main room of the building, desks and computers are stationed to support ongoing research. A ServoDrive speaker located in Building 108 was used to generate tones. The windows of the building are made of glass and are enclosed by wooden frames. The building was chosen for its convenience in location, size, and material characteristics. Figures 1–4 show images of Building 108. In Fig. 1, an image is provided of the back side of Building 108. The windows are evenly spaced out along the building. Ground-truth sensors and video cameras were positioned in the grass space illustrated in the figure. Figure 2 shows the roadside view of Building 108. The entrance to the building is shown in this image. The building's size in its entirety is shown in the side view provided in Fig. 3. Figure 4 shows the spacious room inside of Building 108 used for testing the ServoDrive speaker.

Fig. 1 Building 108 (back view)

Fig. 2 Building 108 (roadside view)

Fig. 3 Building 108 (side view)

Fig. 4 Inside Building 108 (test room), location of ServoDrive speaker

3.2 Test Summary

Imagery of a door and a window were collected using high-speed video cameras. Supporting ground-truth data for the excitation were collected using acoustic microphones, a laser Doppler vibrometer (LDV), and geophones. The speaker generated tones at 19, 28, and 37 Hz. The video cameras used were a Point Grey Camera, a RED Scarlet Dragon Camera, and a Casio Camera that sampled at 200, 240, and 1,200 fps, respectively. Data files measured by these cameras can be accessed in ARL's Automated Online Data Repository (AODR) database.[2,3]

4. Truth Sensors and Supporting Technologies Specifications

This experiment utilized high-speed video cameras to record the local vibrations of a window and door of a building as they were excited by low-level frequency waves generated by the ServoDrive speaker. The following cameras were used to record data: RED Camera, Casio Camera, and Point Grey Camera. Table 1 characterizes the 3 video cameras and the supporting sensing devices used for collecting ground truth data. The table lists the sensing capability of each device, gives the model specifications, and provides an image of the model of the device used during the experiment.

Table 1 Cameras and truth sensors

Sensor	Specifications	Image
Casio Camera Exlim Pro (Ex-Fl)	512*384 @ 300 fps, 432*192 @ 600 fps, 336*96 @ 1200 fps 6.0 Mega Pixels 2.8” Wide & Bright LCD	
RED Scarlet Dragon Camera	6k @ 12fps, 5k @48fps, 4k @ 60 fps, 3k @ 80 fps, 2k @120 fps Rolling Shutter S/N Ratio: 80dB Dynamic Range: 16.5+ Stops	
Point Grey Video Camera	200 fps	
Brüel & Kjaer Microphone	Type 2669 No. 1856889 23/07 (4193 – 20 Gain dB)	
Brüel & Kjaer Foam Microphone	Type 2669 No. 2344712 (4192 – 20 Gain dB)	
ServoDrive Speaker	ITC License CB-1001-136-ETC2/03 Glenview, Illinois	

Sensor	Specifications	Image
National Instruments (NI) CompactRIO Real-Time Controller	cRIO - 9025	
Polytech Laser Doppler Vibrometer	Polytech PDV-100 Frequency range: 0 Hz–22 kHz Range: 0.1–30 m	
Geospace Geophone	Houston, Texas Patent 4594695	

Table 2 lists supporting technology and power supplies used to support the camera and truth sensors. These devices are listed by their name, model specifications, and a photo of the model of the device used during the experiment. The Dual Microphone Supply supported the 2 B&K microphones specified in Table 1. The Crown-Tech 600 was used to drive the ServoDrive speaker. A Dell laptop owned by BAH was used during the experiment for processing and moving data files.

Table 2 Supporting devices and technology

Sensor	Specifications	Image
Dual Microphone Supply	Type 5935L	
Crown Micro-Tech 600		
Data acquisition laptop		
Lithium ion (Li-ION) Sealed: Rechargeable battery	24 V, 7.5 Ah at 2 A, BB-2590/U	
Synthesizer/Function Generator Hewlett Packard		

5. The Experiment

During this experiment, truth sensors were positioned at specific distances away from the ARL Building 108. An LDV sensor was located approximately 25 ft away from the building, while the geophone and 2 microphones were each 20 ft away from the building. The Casio, RED, and Point Grey cameras were each stationed approximately 30, 30, and 15 ft, respectively, from the building. To note, the Point Grey Camera was moved to a greater standoff distance of 130 ft later in the experiment. The cameras and supporting sensors recorded data as the speaker generated tones with frequencies at 19, 28, and 37 Hz. These tones were purposely restricted to low frequencies.

The cameras were focused on either the door or a window. One set of tests used the cameras and truth sensors to record the excitation of a door on the building, while the other test focused on the excitation of a window. The door test began with taking a baseline measurement of the door. This measurement was conducted and recorded 4 consecutive times. The files for these data runs can be found under the "Data Collection Documented" section of this report in Tables 3–7. Video data were collected as the speaker emitted frequencies at 19, 28, and 37 Hz. Approximately 30 s of data were taken during 4 runs. After completing the door test, the window test was conducted.

Images of the experimental setup have been provided in Figs. 5–8. Figure 5 is an image of both the door and window that were excited by the ServoDrive speaker. A piece of retroreflective tape was placed on both objects to provide a reflection for the LDV. A wide-range image of the experimental setup is shown in Fig. 6. This image displays the orientation setup of the Casio, RED, and Point cameras, as well as other supporting sensors. Figure 7 shows the setup of the Casio camera, RED camera, and LDV in relation to each other as they are facing the backside of the building. Figure 8 shows a close-up of the LDV. To note, during the experiment, the LDV at one point overheated. For the duration of the experiment, an umbrella was used to cover it to prevent overheating.

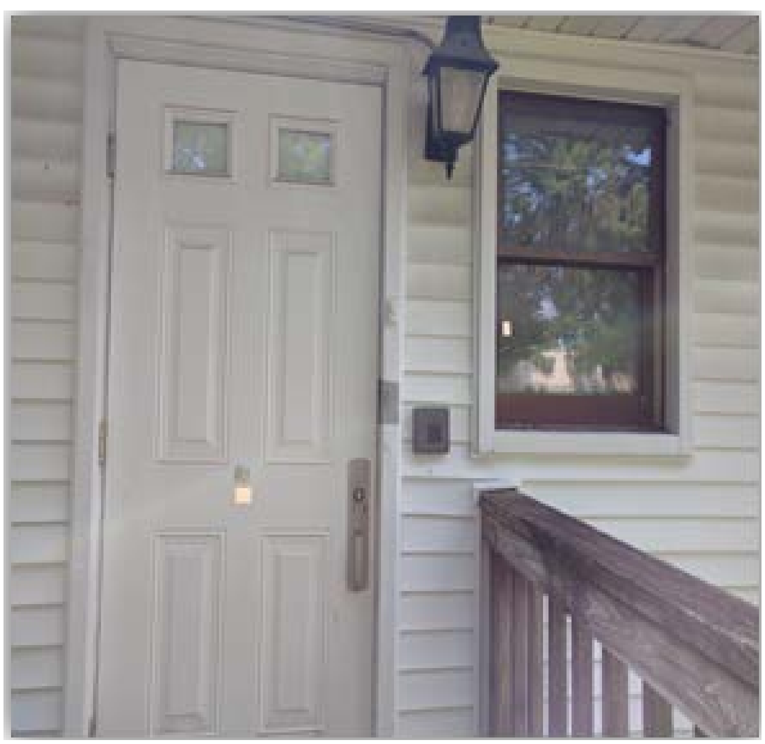

Fig. 5 Zoomed-in image of door and window excited by ServoDrive speaker

Fig. 6 Device setup: Casio camera (left), LDV camera (center), RED camera (right)

Fig. 7 View of cameras and supporting technology

Fig. 8 Umbrella compensates for LDV overheating during test run

6. Signal and Image Processing: Data Analysis

ARL's Acoustic and Electromagnetic Sensing Branch uses 2 techniques to process video data. The first method requires taking a discrete Fourier transform (DFT) of several images that are taken across the time domain. These images are first stacked on top of each other and then a DFT is performed. Finally, the results of the DFTs associated with a small region of interest are noncoherently averaged. For the other method, the consecutive images are correlated to estimate a pixel shift, then a DFT of the results is calculated. In this report, the second method was used to process selected data. Video data were collected from the Casio, RED, and Point Grey cameras, as well as recorded using the LDV, geophone, CompactRIO (cRIO) systems, and the microphones. These devices served as ground-truth data devices to verify the main data collects, the Casio and RED data files. Video data were stored in .MOV, .AVI, and .R3D video files, and the ground-truth data were stored in .BIN files. Imaging data were collected during the day in a relatively quiet environment. Approximately 100 GB of data were collected. Tables 3–7 list the data files collected during the experiment by the various sensors.

7. Data Collection Documented

7.1 Collection Process

The field test data collection process started at approximately 2:30 PM and concluded at approximately 6:00 PM. The following data tables list the data files that were recorded by the cameras and ground-truth sensors during testing. Table 3 documents video files recorded by the Casio Camera. These files were stored in

.MOV format. Approximately 892 MB of data were stored by the camera. These data files, on average, took up about 53 MB of storage for each file. In each of these data collects, the Casio camera recorded either the door or window. The table specifies the object of focus during each test run. The table also includes which frequency the object was excited at and the time the test run occurred. The last column of the table states how large each data file is. There is a division between 2 sets of data taken by the camera in the table. During round 1 of the data collection, the Casio camera was stationed 30 ft away from the building. During round 2, the camera was moved to a standoff distance of approximately 130 ft away from the building. Approximately 100 GB of data were collected during the test.

Table 3 File descriptions for Casio camera data

File Name	**Object Excited**	**Frequency (Hz)**	**Time Stamp**	**File Size**
ROUND 1 (30 FT)	**ROUND 1 (30 FT)**	**ROUND 1 (30 FT)**	**ROUND 1 (30 FT)**	**ROUND 1 (30 FT)**
CIMG0006.JPEG	Door			1.63 MB
CIMG0006.mov	Window			74.1 MB
CIMG0007.JPEG	Door		3:52	1.61 MB
CIMG0007.mov	Window			85.7 MB
CIMG0008.mov	Window	37		58.6 MB
CIMG0009.mov	Window	37		68.6 MB
CIMG0010.mov	Window	37	4:28	52.1 MB
CIMG0011.mov	Window	28	4:38	63.8 MB
CIMG0012.mov	Window	28	4:41	42.8 MB
ROUND 2 (130 FT)	**ROUND 2 (130 FT)**	**ROUND 2 (130 FT)**	**ROUND 2 (130 FT)**	**ROUND 2 (130 FT)**
CIMG0002.mov	Window	19	4:50	69.6 MB
CIMG0003.mov	Window	19	4:53	58.9 MB
CIMG0004.mov	Window	Baseline	4:57	58.1 MB
CIMG0005.mov	Door	Baseline	5:25	54.5 MB
CIMG0008.mov	Door	19	5:35	35.8 MB
CIMG0009.mov	Door	37	5:39	61.8 MB
CIMG00010.mov	Door	37	5:40	52.8 MB
CIMG0011.mov	Door	Baseline		51.5 MB

Video files recorded by the RED Camera are listed in Table 4. These files were stored in .RDC format. Approximately 30 GB of data were stored by the camera.

These data files, on average, took up about 1.7 GB of storage for each file. In each of these data collects, the RED camera recorded either the door or window. The table specifies the object of focus during each test run. The table also includes which frequency the object was excited at and the time the test run occurred. The last column of the table states how large the data file is. The video files were taken 30 ft away from the building.

Table 4 File descriptions of RED camera data

File Name	Object Excited	Frequency (Hz)	Time Stamp	File Size
A004_C035_060157.RDC	Door			1.40 GB
A004_C036_0601QS.RDC	Door			717 MB
A004_C038_0601O7.RDC	Window			1.00 GB
A004_C039_0601F4.RDC	Window			503 MB
A004_C042_0601W0.RDC	Window	Baseline		2.46 GB
A004_C043_0601ZZ.RDC	Window			1.77 GB
A004_C044_06014R.RDC	Window			2.12 GB
A004_C045_0601IB.RDC	Window			404 MB
A004_C046_0601MS.RDC	Window			237 MB
A004_C047_0601H0.RDC	Window	37	4:28	2.10 GB
A004_C048_06018Q.RDC	Window	28	4:38	2.46 GB
A004_C049_0601SQ.RDC	Window	28	4:41	2.26 GB
A004_C050_06018Y.RDC	Window	19	4:50	2.59 GB
A004_C051_0601XC.RDC	Window	19	4:53	2.15 GB
A004_C052_0601OW.RDC	Window	Baseline	4:57	2.10 GB
A004_C053_060187.RDC	Door	Baseline	5:25	2.11 GB
A004_C054_060153.RDC	Door	19		2.11 GB
A004_C055_0601H5.RDC	Door	19	5:35	2.30 GB
A004_C056_0601ME.RDC	Door	37	5:39	2.27 GB
A004_C057_0601RY.RDC	Door	37	5:40	2.09 GB
A004_C058_06019D.RDC	Door	Baseline		2.07 GB
A004_C059_0601Y3.RDC	Door			975 MB
A004_C060_0601XO.RDC	Door			215 MB

Video files recorded by the Point Grey Camera are listed in Table 5. These files were stored in .AVI format. Approximately 63 GB of data were stored by the camera. These data files, on average, took up about 1.7 GB of storage for each file. In each of these data collects, the Point Grey camera recorded imagery of either the door or window. The table specifies the object of focus during each test run. The

table also includes which frequency the object was excited at and the time the data trial occurred. The last column of the table states how large the data file is. There are 2 sets of data taken by the Point Grey camera in the table. During round 1 of the data collect, the Point Grey camera was stationed 15 ft away from the building. During round 2, the camera was moved to a standoff distance of 30 ft away from the building.

Table 5 File descriptions of Point Grey camera data

File Name ROUND 1 (15 FEET)	Object Excited ROUND 1 (15 FEET)	Frequency (Hz) ROUND 1 (15 FEET)	Time Stamp ROUND 1 (15 FEET)	File Size ROUND 1 (15 FEET)
PG_WINDOW_BASELINE_C1_0	Window	Baseline		1.99 GB
PG_WINDOW_BASELINE_C1_1	Window	Baseline		1.99 GB
PG_WINDOW_BASELINE_C1_2	Window	Baseline		1.14 GB
PG_WINDOW_BASELINE_C2_0	Window	Baseline		1.99 GB
PG_WINDOW_BASELINE_C2_1	Window	Baseline		1.99 GB
PG_WINDOW_BASELINE_C2_2	Window	Baseline		1.14 GB
PG_WINDOW_BASELINE_C2_2_2016-06-01-165710-0002	Window	Baseline		1.99 GB
PG_WINDOW_SPEAKER_19Hz_C1_0	Window	19		1.99 GB
PG_WINDOW_SPEAKER_19Hz_C1_0	Window	19		1.99 GB
PG_WINDOW_SPEAKER_19Hz_C1_2	Window	19		1.14 GB
PG_WINDOW_SPEAKER_19Hz_C2_0	Window	19		1.99 GB
PG_WINDOW_SPEAKER_19Hz_C2_1	Window	19		1.99 GB
PG_WINDOW_SPEAKER_19Hz_C2_2	Window	19		1.14 GB
PG_WINDOW_SPEAKER_28Hz_C1_0	Window	28		1.99 GB
PG_WINDOW_SPEAKER_28Hz_C1_1	Window	28		1.99 GB
PG_WINDOW_SPEAKER_28Hz_C1_2	Window	28		1.14 GB
PG_WINDOW_SPEAKER_28Hz_C2_0	Window	28		1.99 GB
PG_WINDOW_SPEAKER_28Hz_C2_1	Window	28		1.99 GB
PG_WINDOW_SPEAKER_28Hz_C2_2	Window	28		1.14 GB
PG_WINDOW_SPEAKER_37Hz_C1_0	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C1_1	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C1_2	Window	37		1.14 GB
PG_WINDOW_SPEAKER_37Hz_C2_0	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C2_1	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C2_2	Window	37		1.14 GB

File Name	Object Excited	Frequency (Hz)	Time Stamp	File Size
ROUND 1 (15 FEET)	**ROUND 1 (15 FEET)**	**ROUND 1 (15 FEET)**	**ROUND 1 (15 FEET)**	**ROUND 1 (15 FEET)**
PG_WINDOW_SPEAKER_37Hz_C3_0	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C3_1	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C3_2	Window	37		1.14 GB
PG_WINDOW_SPEAKER_37Hz_C4_0	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C4_1	Window	37		1.99 GB
PG_WINDOW_SPEAKER_37Hz_C4_2	Window	37		1.14 GB
ROUND 2 (30 FEET)	**ROUND 2 (30 FEET)**	**ROUND 2 (30 FEET)**	**ROUND 2 (30 FEET)**	**ROUND 2 (30 FEET)**
PG_WINDOW_37Hz_FAR_C1_2016-06-01-175822-0000.avi	Window	37		1.99 GB
PG_WINDOW_37Hz_FAR_C1_2016-06-01-175822-0001.avi	Window	37		1.99 GB
PG_WINDOW_37Hz_FAR_C1_2016-06-01-175822-0002.avi	Window	37		1.14 GB
PG_WINDOW_37Hz_FAR_C2_2016-06-01-180022-0000.avi	Window	37		1.99 GB
PG_WINDOW_37Hz_FAR_C2_2016-06-01-180022-0001.avi	Window	37		1.99 GB
PG_WINDOW_37Hz_FAR_C2_2016-06-01-180022-0002.avi	Window	37		1.14 GB

Table 6 lists the 7 connection ports that were used by the cRIO data acquisition device. Each of the 7 channels was connected to one of the ground-truth sensors. Channel 1 was connected to the LDV; Channel 2 was connected to the foam ball microphone; Channel 4 was connected to the 2-3 port of the geophone; Channel 5 was connected to the 2-4 port of the geophone; Channel 6 was connected to the 2-5 port of the geophone; and Channel 7 was connected to the ball microphone without foam. Channel 3 of the cRIO was not connected to any input device.

Table 6 cRIO channel connection descriptions

Channel	Sensor
1	Laser Doppler vibrometer
2	B&K microphone with foam ball 4192 - 20 gain dB
3	Disconnected
4	2-3 Geophone port
5	2-4 Geophone port
6	2-5 Geophone port
7	B&K microphone uc011 adapter bmk 4193 - 20 gain dB

Table 7 lists the data files recorded by the cRIO data acquisition system. These files were stored in .BIN format. Approximately 88 MB of data were stored by the cRIO device. These data files took up about 6 MB of storage on average for each file. In each of these data collects, the cRIO device recorded either the door or window. The table specifies the object of focus. The table also includes which frequency the specified object of interest was excited at and the time the data trial occurred. The last column of the table states how large the data file is.

Table 7 File descriptions of cRIO data

File Name	Object Excited	Frequency (Hz)	Time Stamp	File Size
AD_DOOR_BASELINE_C1.bin	Door	Baseline		6.48 MB
AD_DOOR_SPEAKER_19Hz_C1.bin	Door	19		2.47 MB
AD_DOOR_SPEAKER_19Hz_C2.bin	Door	19		4.57 MB
AD_DOOR_SPEAKER_37Hz_C1.bin	Door	37		6.10 MB
AD_DOOR_SPEAKER_37Hz_C2.bin	Door	37		4.00 MB
AD_WINDOW_BASELINE_C1.bin	Window	Baseline		6.67 MB
AD_WINDOW_BASELINE_C2.bin	Window	Baseline		6.10 MB
AD_WINDOW_SPEAKER_19Hz_C1.bin	Window	19		7.24 MB
AD_WINDOW_SPEAKER_19Hz_C2.bin	Window	19		6.10 MB
AD_WINDOW_SPEAKER_28Hz_C1.bin	Window	28		7.24 MB
AD_WINDOW_SPEAKER_28Hz_C2.bin	Window	28		6.29 MB
AD_WINDOW_SPEAKER_37Hz_C1.bin	Window	37		6.29 MB
AD_WINDOW_SPEAKER_37Hz_C2.bin	Window	37		6.48 MB
AD_WINDOW_SPEAKER_37Hz_C3.bin	Window	37		7.81 MB
AD_WINDOW_SPEAKER_37Hz_C4.bin	Window	37		4.18 MB

7.2 Sample Example of Processing Data Files

The following figures display some of the images and graphs that represent data generated from ARL's image and signal processing algorithms. Figure 9 shows 2 images taken by the RED and Casio cameras of the reflective tape that was used on the door to obtain adequate measurements from the LDV.

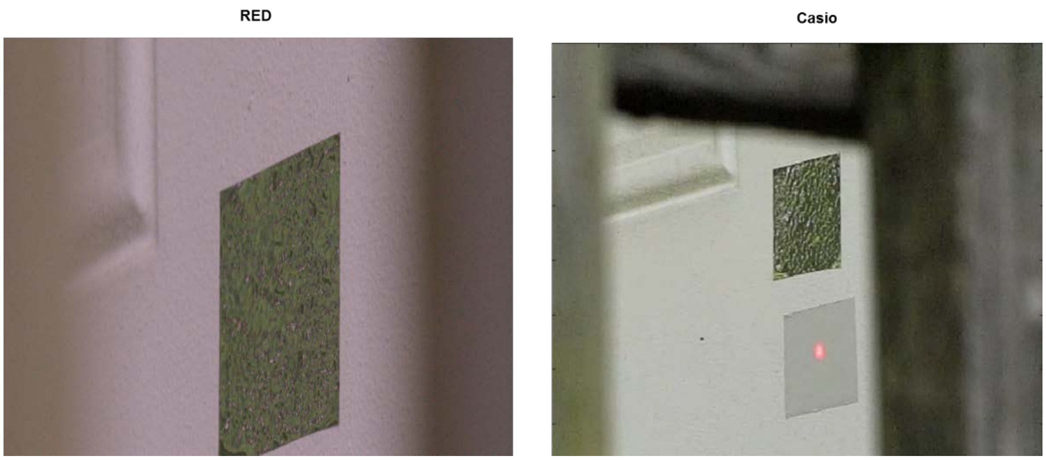

Fig. 9 Door experiment: speaker at 19 Hz, visual image through camera lens: RED (left), Casio (right)

Figure 10 shows the spectrum of the processed data versus the time of the door being excited by a 19-Hz tone. The solid yellow lines in the 2 graphs verify that a 19-Hz signal was detected by both the RED and Casio cameras. This yellow line clearly stands out in both graphs.

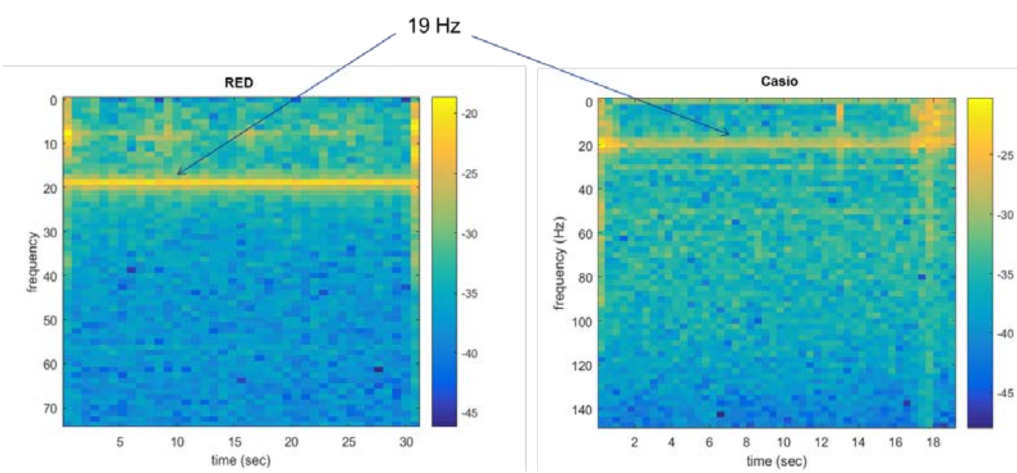

Fig. 10 Door experiment: speaker at 19 Hz, frequency vs. time: RED (left), Casio (right)

Figures 11 through 15 display the spectrum versus time measurements for the LDV, microphones, and geophones. These graphs verify that the speaker generated tones

at 19 Hz. These figures provide ground truth data for the RED and Casio cameras, confirming that the data results taken from the cameras' readings are accurate. In Fig. 11, the LDV and the microphone data show a clear indication of detection of 19 Hz tone, while the results for the 2-3 geophone connection data are a little less evident. The harmonics 19, 38, 57, 76, and 95 are clearly evident in the LDV graph. The solid reddish-brown line in the microphone data graph shows a clear indication of the detection of the 19-Hz tone.

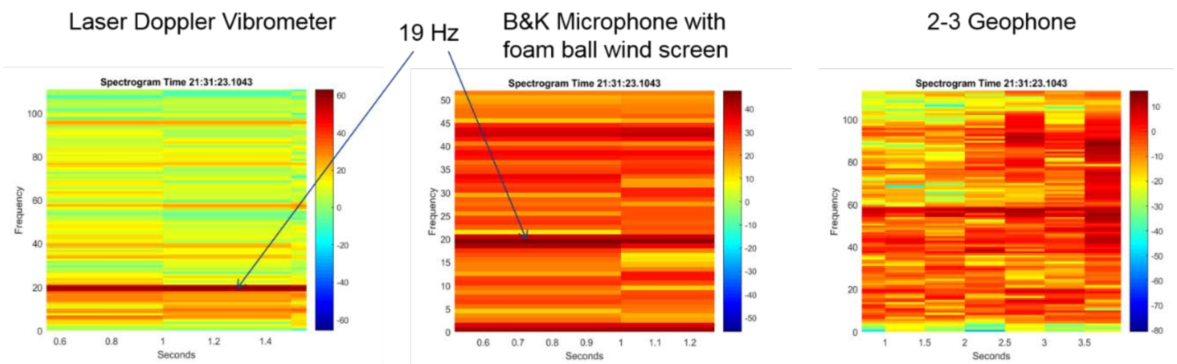

Fig. 11 Door experiment: speaker at 19 Hz, frequency vs. time: LDV (left), foam mic (middle), 2-3 geophone connect (right)

Figure 12 displays 2 data graphs of the spectrum versus time of the LDV data. The graph on the right illustrates a zoomed-in view of the data plotted in the left graph. The right-hand graph clearly shows the fundamental frequency at 19 Hz and its harmonics.

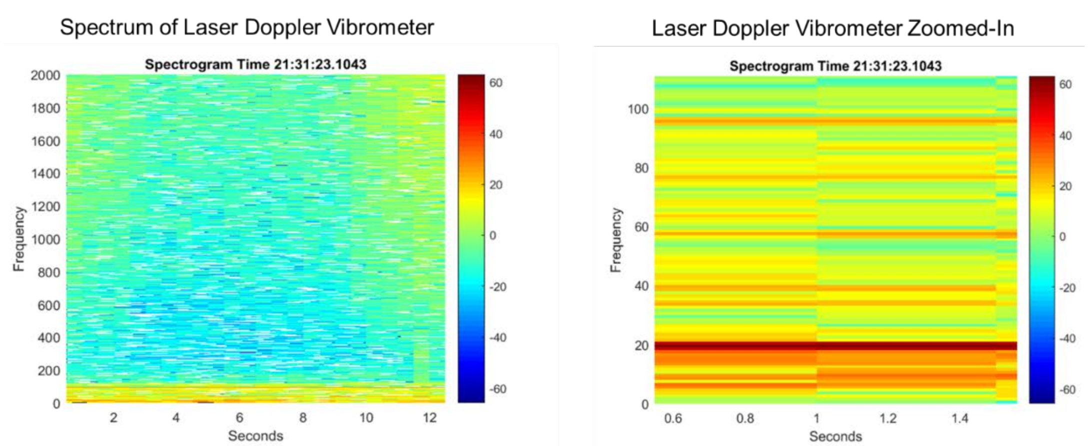

Fig. 12 Door experiment: speaker at 19 Hz, frequency vs. time: LDV data (left), LDV data zoomed-in (right)

Figure 13 displays the spectrum of 2 data graphs that represent data collected by the B&K microphone with a foam wind screen. The graph on the right illustrates a

zoomed-in view of the data plotted in the left graph. The right-hand graph clearly shows the fundamental frequency at 19 Hz.

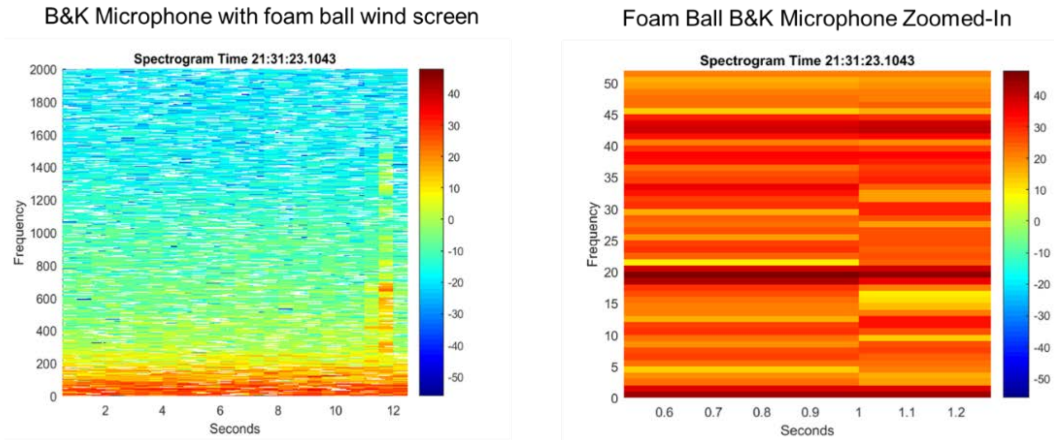

Fig. 13 Door experiment: speaker at 19 Hz, frequency vs. time: foam mic data (left), foam mic data zoomed-in (right)

Figure 14 displays 2 data graphs that represent data collected by the geophone connection labeled 2-3. The graph on the right illustrates a zoomed-in view of the data plotted in the left graph. The detection of the 19-Hz signal in data graph on the right is less obvious compared to data collected by the cameras, microphones, and the LDV.

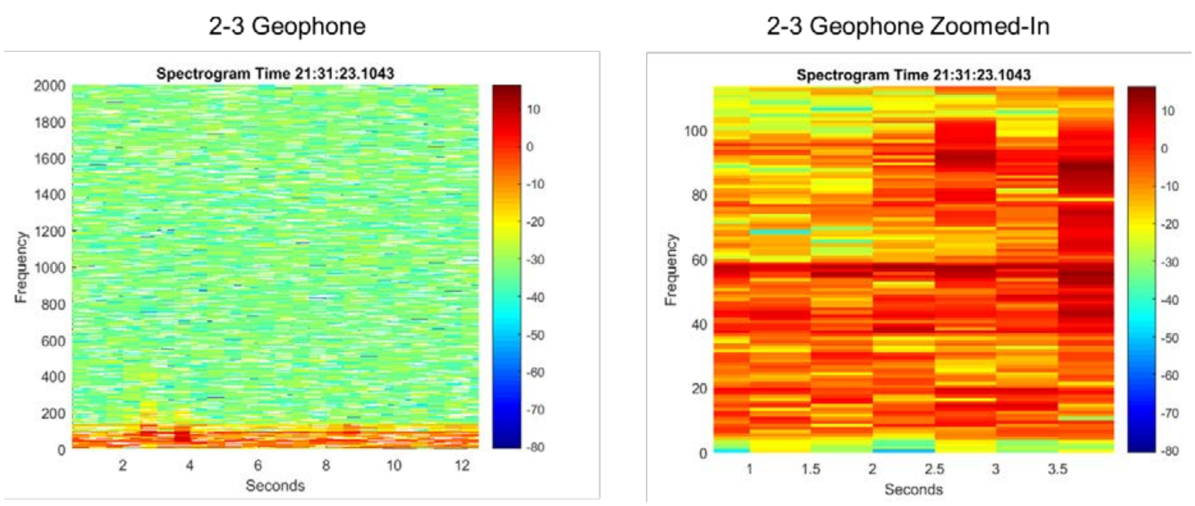

Fig. 14 Door experiment: speaker at 19 Hz, frequency vs. time: 2-3 geophone connect data (left), 2-3 geophone connect data zoomed-in (right)

Figure 15 displays the frequency versus time graphs for the 2 geophone channels, 2-4 and 2-5, as well as the microphone without a wind screen. The geophone and

microphone results both show a tone at of 19 Hz. The geophone results have lower SNRs compared to the other sensors used in this experiment.

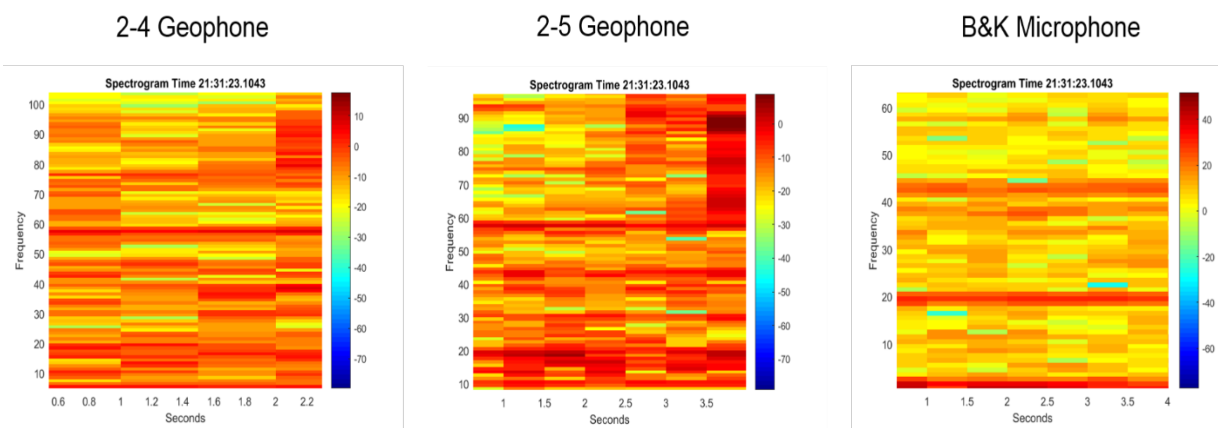

Fig. 15 Door experiment: speaker at 19 Hz, frequency vs. time: 2-4 geophone (left), 2-5 geophone connect (center), standard mic (right)

The data were affected by several factors during the experiment. Specifically, wind affected imagery by blowing the leaves and trees in the imagery. In addition, noise from ongoing traffic coming from Powder Mill Road near ARL's facility may have contributed to additional noise noticeable in the processed imagery. In this experiment, there were a few time delays in the start of the devices. The cRIO device had a time delay. In addition, sometimes the devices did not start in sync with the other devices, or they would shut off during the experiment.

8. Conclusions and Considerations

ARL and BAH conducted a field test that was designed to assess how high-speed video cameras can be used to detect sound. The team measured video camera data from a RED Scarlet Dragon Camera, a Casio Camera, and a Point Grey Camera while a building was excited by a low-frequency ServoDrive speaker inside of ARL's Building 108 facility. The field test and the data collected are documented in this report. The team developed image processing algorithms to analyze the results and successfully verified that the cameras and other devices correctly estimated the frequency of the tone generated at each trial.

9. References

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List of Symbols, Abbreviations, and Acronyms

AODR	Automated Online Data Repository
ARL	US Army Research Laboratory
BAH	Booz Allen Hamilton
cRIO	CompactRIO
DFT	discrete Fourier transform
LDV	laser Doppler vibrometer
SNR	signal-to-noise ratio

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